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A DIGITAL POINT GAGE RECORDER

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A DIGITAL POINT GAGE RECORDER[1]

Fred W. Blaisdell[2] and Scott D. Crist[3]

INTRODUCTION

Equipment for recording point gage readings directly on punched tape in a form suitable for use by a digital computer is described.

The components of the digital point gage recorder include a point gage, gears to convert point gage linear motion to rotation of a shaft, an analog-to-digital converter (encoder) to change the angular position of the shaft into a coded digital output, a control cabinet to read the converter, and a tape punch to record the coded readings on paper tape. A keyboard on the control cabinet permits the entry of certain data on the paper tape more conveniently than through the point gage.

Readout is initiated by the observer's pushing a switch button. For reasons associated with the test methods, this semiautomatic initiation of readout was preferred. Readout could be initiated automatically by the addition of suitable components. The readout time is less than one second.

The equipment is adaptable for recording any information that can be converted into a shaft rotation. The possible adaptation of the equipment to other uses is the reason for reporting this development. The report consists of a description of (1) the design and operation of the digital point gage recorder, (2) operational difficulties and adjustments, and (3) performance checks.

THE NEED

Digital computers have been used to perform the routine preliminary analysis of data obtained from tests of closed conduit spillways made by the Agricultural Research Service at the St. Anthony Falls Hydraulic Laboratory since 1958. This has saved considerable time and has increased the volume of work produced. However, before the development of the digital point gage recorder, it was necessary to record the point gage readings manually and subsequently punch them on paper tape in a code acceptable to the computer. The punching and checking ordinarily required several days. During this period the test equipment often was idle because subsequent tests frequently depended on the results of the previous tests. It appeared that semiautomatic recording of the data on tape would eliminate this waiting period, reduce costs, and increase the output from the experimental apparatus.

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Direct, semiautomatic recording of coded point gage readings on punched tape would eliminate visual reading of the point gage, the initial pencil recording of the data, and the subsequent punching of coded readings on the computer input tapes. On completion of each test, the data would be ready for the computer. In view of the lengthy test program anticipated and the potential savings in time and cost, the digital point gage recorder was developed.[4]

PRINCIPLE OF OPERATION

The equipment for digital recording is contained in three separate units—an encoder unit, a control cabinet, and a tape punch. These are shown from right to left in figure 1.

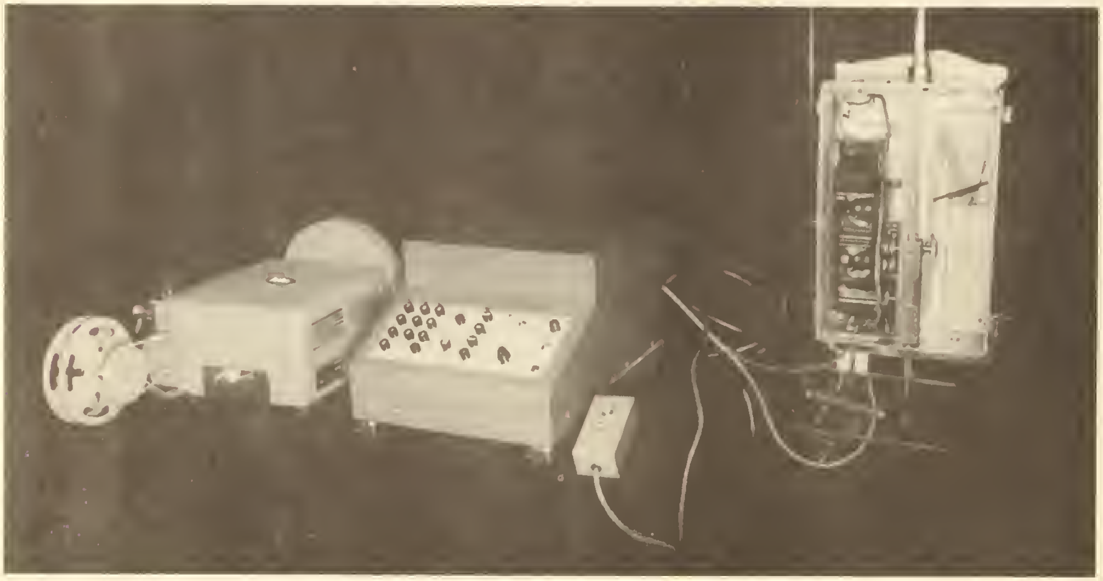

Figure 1.—Tape punch, control cabinet, and encoder unit.

A point gage in the encoder unit is adjusted manually. The point gage reading is transmitted through gears to an analog-to-digital converter. The angular position of the converter input shaft is converted to electrical contacts by means of sensing pins which bear on serrated code wheels when the sensing head is dropped onto the code drums. The sensing head is operated by a solenoid when the readout button is pushed.

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[4] The digital point gage recorder was conceived by the senior author. The initial detailed design was by William Bechtold, engineering assistant, St. Anthony Falls Hydraulic Laboratory, University of Minnesota. The final detailed design, assembly, and debugging were by the junior author. Many other persons contributed ideas and information which are herewith acknowledged with thanks.

When the readout, or sweep-start, button is pushed, each of the closed analog-to-digital converter contacts, which represents one of the four digits of the point gage reading, is converted to a code acceptable to the computer by a diode matrix. The diode matrix code in turn selects the combination of punches on a tape punch that are to be energized during the coded readout of each digit.

A rotary stepping switch reads out each point gage digit in proper sequence by completing the circuit to each of the four closed encoder contacts, the proper diode matrix code, and the selected combination of tape punches, as it sweeps out a cycle. Computer operational codes and a decimal are inserted into the sequence at predetermined locations. After each single punch operation, cam-operated contacts in the tape punch cause the stepping switch to advance to the next readout position. This is repeated until the programmed cycle has been completed. The four point gage digits plus appropriate computer codes have then been read and punched into the paper tape in proper sequence and the equipment is ready to accept the next reading.

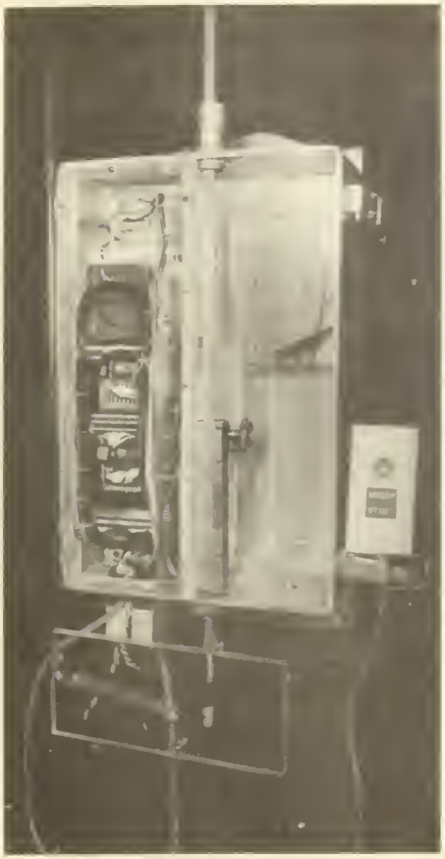

Figure 2.—Encoder unit, consisting of encoder, point gage, and readout button.

The tape punch can also be operated through a keyboard on the control cabinet. A switch selects either keyboard or encoder input to the punch. The keyboard is provided because it is more convenient to enter some information on the tape through the keyboard rather than through the point gage.

DETAILS OF DESIGN

The details of design of the major components of the digital point gage recorder—the encoder unit, the control cabinet, and the tape punch—are given in this section.

Encoder Unit

The analog-to-digital encoder and the point gage are mounted in a salvaged case for a Friez FD-4 water level recorder.[5] Figure 2 shows the complete encoder unit.

The point gage is an A.B. McIntyre Lory type A gage with a square shaft. Its range is 3 feet. A vernier permits direct reading to 0.001 foot. A rack on the back of the shaft is used to adjust its vertical position through a pinion and hand wheel.

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[5] Trade names are used in this publication solely for the purpose of providing specific information. Mention of a trade name does not constitute a guaranty or warranty of the product by the U.S. Department of Agriculture or an endorsement by the Department over other products not mentioned.

The gear train between the point gage and the encoder multiplies the shaft movement so that each count on the encoder represents about 0.0006 foot of shaft movement. This makes the precision of each count approximately equal to the precision of the point gage. Antibacklash gears are used where advantageous in order to eliminate play between gears. The gears are pinned to the drive shaft to prevent slippage, except that the final gear in the train is clamped to the encoder input shaft so it can be slipped on the shaft and the point gage zero adjusted to the encoder zero.

The encoder is a Fischer & Porter Model 32AA2 Digi-Coder. Important parts are the detent wheel and pin, the code drums and wheels, the sensing pins, the electrical contacts, and the sensing heads and solenoid. Most of these parts are shown in figure 3.

The detent wheel and the code drums that read units and tens are mounted on the input shaft. The code drums for hundreds and thousands are mounted on a separate shaft and geared to the input shaft in a 100-to-1 ratio. The detent pin engages the detent wheel when the sensing head drops to the readout position. This locks the code drums in position during readout. The detent pin also positions the code drums to insure correct readout. In positioning the code drums, the detent pin may move these drums as much as one-half unit.

The code wheels have "plateaus," "hills," and "valleys," as shown in figure 3. Sensing pins contact these plateaus, hills, or valleys when the solenoid is energized to drop the sensing head to the readout position. When the sensing pin engages a hill

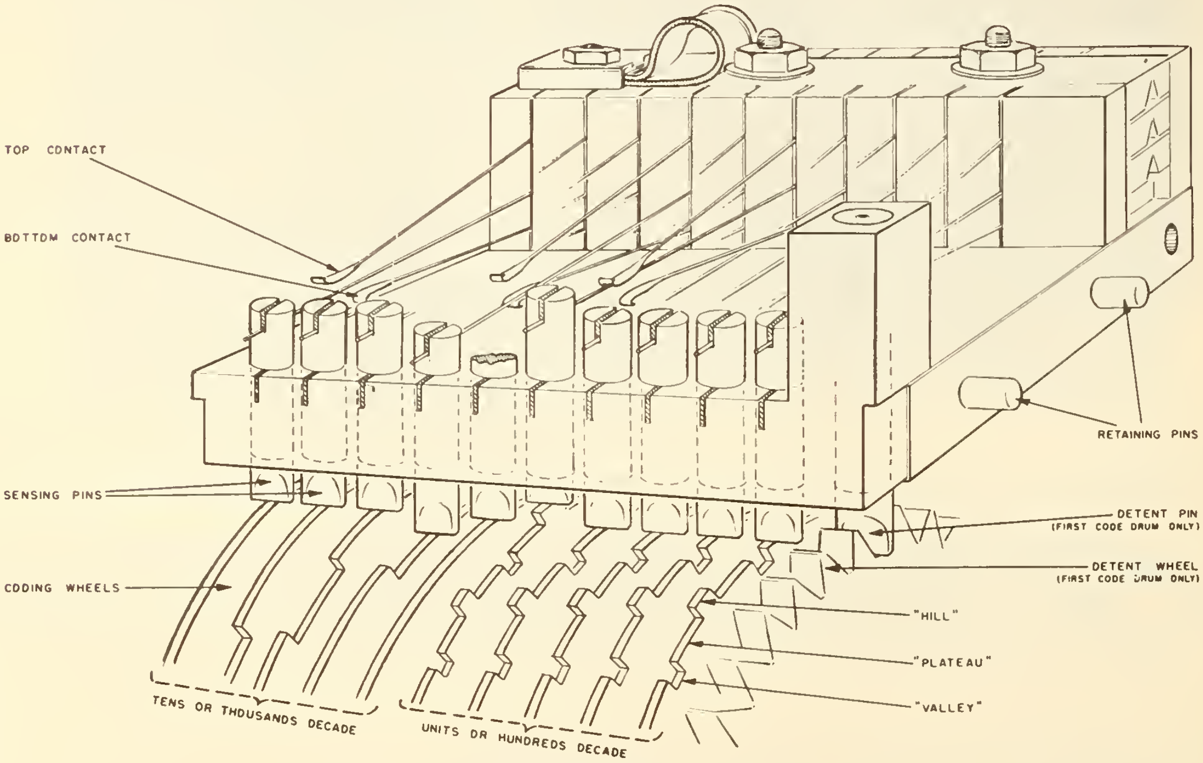

Figure 3.—Digi-Coder wheels and sensing head.

or a valley, an upper or lower electrical contact is made. In this way the analog position of the input shaft and, as a result, the analog position of the point gage are converted into four digital electric contacts representing the units, tens, hundreds, and thousands digits. Each terminal of each contact is wired to an external connector. No contact is closed when the sensing pin touches a plateau.

The solenoid that operates the sensing head has its own power supply and is energized from an external source. A button, labeled "sweep start" in figure 2, is depressed manually to initiate readout for the digital point gage recorder.

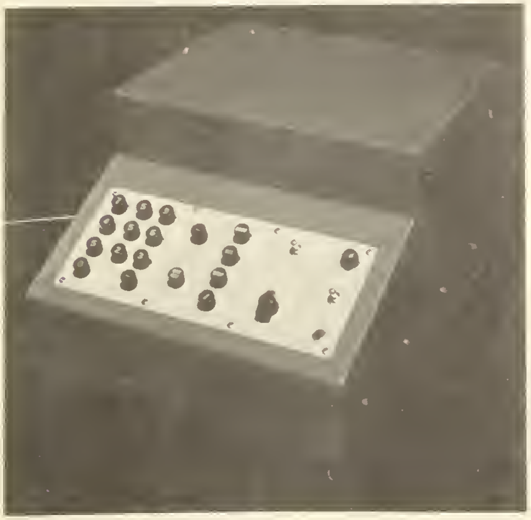

Figure 4.—Control cabinet.

The Digi-Coder is designed as a static readout device and dynamic readout is not recommended by the manufacturer. This means that the point gage cannot be moved for the approximate one second required for the readout. This static readout is not an important limitation for the present installation. However, after the Digi-Coder had been ordered, attention was called to the Mem-O-Tizer, manufactured by the Telemet Corp.

The Mem-O-Tizer accepts dynamic readout, has a readout time of 0.050 second, and remembers each reading until the next readout. Other features are comparable to those contained in the Digi-Coder.

The Digi-Coder is covered with the plastic case shown in figure 2 to prevent entry of dust. Cable connectors for the sensing pin contacts are mounted outside the water level recorder case. Cables for solenoid operation and power supply also are brought out through the case.

Control Cabinet

The control cabinet contains all the circuits, switches, and relays required to read the encoder contacts and transmit the readings to the tape punch. As can be seen in figure 4, a combination keyboard and control panel is located at the front of the control cabinet. At the rear are connectors to the encoder and to the tape punch, power supply outlets for the encoder and punch, and a main power supply cable.

The circuit elements contained in the control cabinet are identified in the block diagram (fig. 5) and in the circuit diagram (fig. 6).

Power Supply

The d.c. power supply consists of a 48-v. a.c., step-down transformer and a silicon diode, full-wave bridge rectifier followed by an electrolytic capacitor (C_1 in

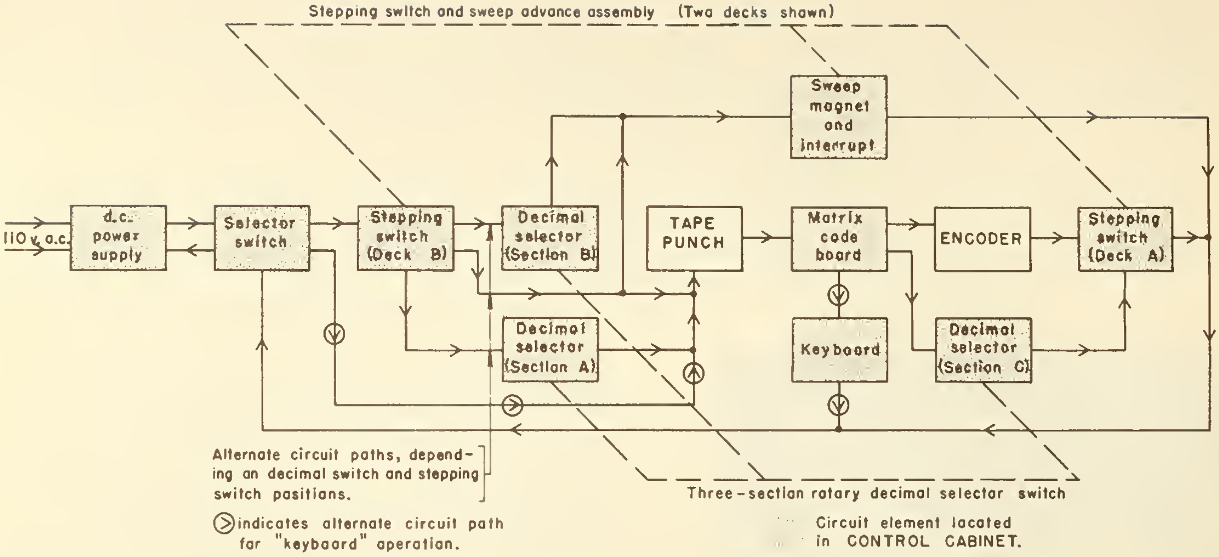
Stepping switch and sweep advance assembly (Two decks shown)
Sweep magnet and interrupt
110 v. a.c.
d.c. power supply
Selector switch
Stepping switch (Deck B)
Decimal selector (Section B)
TAPE PUNCH
Matrix code board
ENCODER
Stepping switch (Deck A)
Decimal selector (Section A)
Keyboard
Decimal selector (Section C)
Alternate circuit paths, depending on decimal switch and stepping switch positions.
Three-section rotary decimal selector switch
indicates alternate circuit path for "keyboard" operation.
Circuit element located in CONTROL CABINET.

Figure 5.—Block diagram of basic control circuit elements.

fig. 6) that provides one section of filtering. The no-load output voltage is approximately 75 volts; the exact voltage depends on the line voltage. Resistors R3 and R4 in figure 6 drop the output voltage to approximately 50 volts under full load, which is the required voltage for the various control and punch magnets.

Control Panel

The control panel shown at the right in figure 7 is made up of a power switch and pilot light, a selector switch, a tape-feed switch, and a decimal selector switch.

The power switch is a double-pole, double-throw (d.p.d.t.) toggle switch which turns on the d.c. power supply and the 110-v. auxiliary receptacles on the rear of the chassis. The lighted pilot light indicates that the power switch is in the "on" position.

The selector switch is a d.p.d.t. toggle switch that switches the output of the power supply to various locations in the circuit depending on whether the keyboard or the encoder is to be used.

The tape-feed switch is a s.p.s.t. momentary contact switch that is used to expel unpunched tape from the tape punch. It is connected in parallel with the tape-feed switch on the tape punch.

The decimal selector switch is a 5-position, 3-section, rotary wafer-type switch. It permits a decimal point to be inserted anywhere among the four readout digits by inserting the decimal code in proper sequence during the stepping switch sweep cycle. Section B of the decimal selector switch is shorting and advances the stepping switch to the next digit readout position at all decimal positions except the

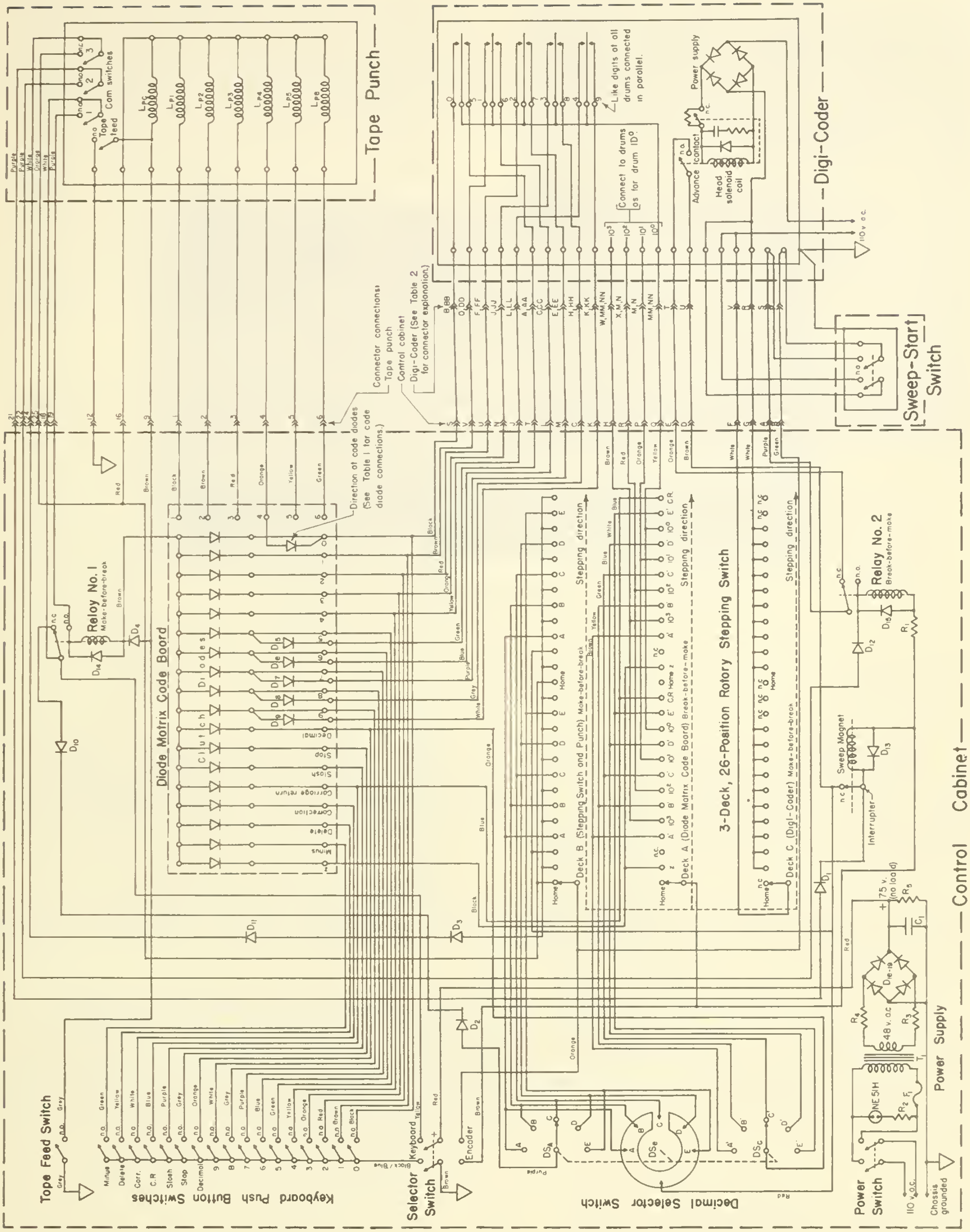
Tape Punch
Cam switches
Tape feed
Digi-Coder
Power supply
Advance contact
Head solenoid coil
Like digits of all drums connected in parallel.
Connect to drums as for drum 10⁰
110 v. a.c.
Connector connections:
Tape punch
Control cabinet
Digi-Coder (See Table 2 for connector explanation.)
Direction of code diodes (See Table 1 for code diode connections.)
Sweep-Start Switch
Diode Matrix Code Board
Clutch
Diodes
Relay No. 1 Make-before-break
Relay No. 2 Break-before-make
3-Deck, 26-Position Rotory Stepping Switch
Deck A (Diode Matrix Code Board) Break-before-make
Deck B (Stepping Switch and Punch) Make-before-break
Deck C (Digi-Coder) Make-before-break
Stepping direction
Sweep Magnet
Interrupter
Control Cabinet
Tape Feed Switch
Keyboard Push Button Switches
Minus
Delete
Corr.
C.R.
Slash
Stop
Decimal
Selector Switch
Keyboard
Encoder
Decimal Selector Switch
Power Switch
110 v. a.c.
Chassis grounded
Power Supply
48 v. a.c.
75 v. (no load)
NE 51H

Figure 6.—Circuit diagram.

selected decimal position. Section A is non-shorting and supplies current to the tape-punch clutch and punch magnets in the selected decimal position only. It also supplies current to the sweep magnet to advance the stepping switch after the decimal code has been punched. Section C is also non-shorting and completes the decimal code circuit from the diode matrix code board to the stepping switch in the selected decimal position.

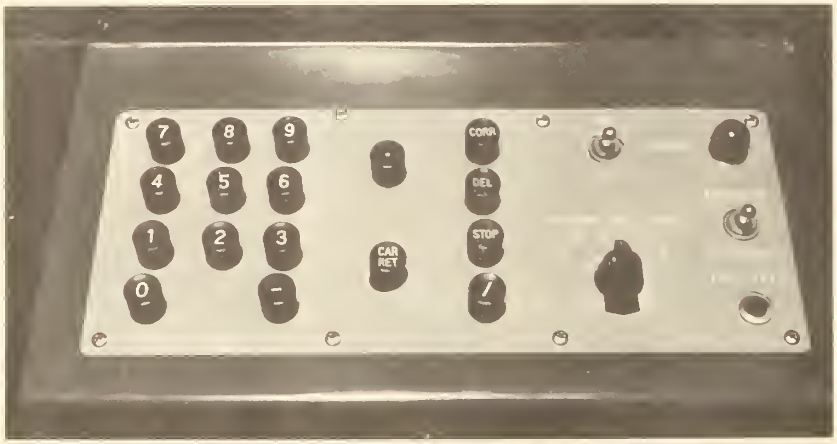

Figure 7.—Front of control cabinet showing keyboard (round buttons at left) and control panel (right).

Keyboard

The keyboard is provided to punch information other than point gage readings on the computer tape. This was a relatively simple addition since the tape punch, the diode matrix codes, and most of the circuit were already available. Figure 7 is a photograph of the keyboard. Selection of keyboard or encoder operation is made by the selector switch on the control panel.

The flexibility of the equipment is increased by the keyboard because it enables the control cabinet and tape punch to be separated from the encoder, if this is desired, and used together in another location.

The 17-button keyboard consists of d.p.s.t., momentary contact, keyboard type push-button switches. Only one section, the normally open contacts, is used in the circuit. The push-button switches permit the digits 0 to 9, minus, decimal point, correction, delete, and various computer operation codes to be punched on tape by completing the circuit to the diode matrix code board that codes the selected character to be punched.

Diode Matrix Code Board

The diode matrix code board shown in figures 5, 6, and 8 consists of a prepunched terminal board supporting spring-loaded mounting clips in which a predetermined arrangement or matrix of diodes is mounted and wired. The diode matrix circuit consists of two sections. The code section provides a coded readout for each of the ten digits (0 to 9), minus, decimal point, correction, delete, and various computer operation codes by selecting a combination of the six punches for each character. The diode matrix code board layout shown in table 1 should be consulted for the specific diode arrangement and wiring. The tape-punch clutch-control section permits the tape-punch clutch magnet to operate simultaneously with any digit or operational function selected by either the keyboard or the encoder.

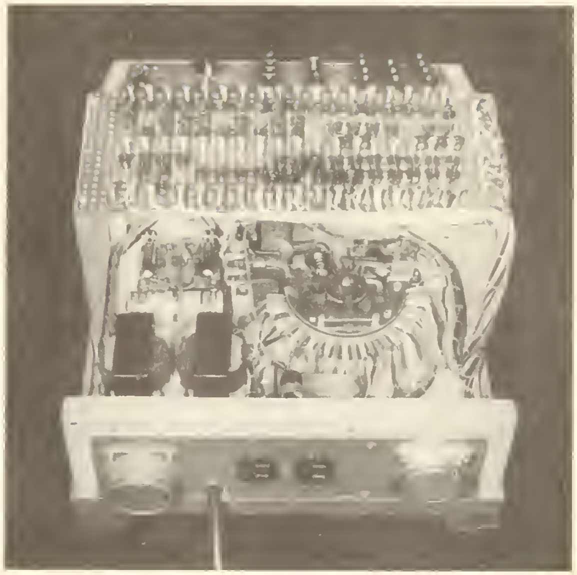

Figure 8.—Rear of control cabinet with cover removed. From top to bottom: control panel and keyboard, diode matrix code board, power supply (left), stepping switch (right), and rear connector panel.

Stepping Switch

The stepping switch is an Automatic Electric 3-deck, 26-position rotary switch with a built-in electromechanical (sweep magnet and spring) contact advance and interrupter switch. In the circuit, the stepping switch is advanced in a cyclic manner to read out the coded data by either its interrupter switch or by a cam switch in the tape punch. Deck B, make-before-break, supplies current to the tape-punch clutch and punch magnets and to the interrupter advance switch through decimal selector switch Section B, depending on its position. Deck A, break-before-make, completes the Digi-Coder-selected matrix-coded punch circuits in proper readout sequence. Deck C, make-before-break, keeps the Digi-Coder heads down in readout position during the readout cycle.

Relays

There are two s.p.d.t. relays used in the circuit. Relay No. 1 has make-before-break contacts and is used to permit only one punch operation per keyboard button depression. Relay No. 2 has break-before-make contacts and is used to permit only one readout cycle per sweep-start button depression.

Connectors

The wiring of the connectors for the cable connecting the Digi-Coder to the control cabinet is given in table 2.

TABLE 1.—Diode matrix code board layout for Control Data 160A computer

[Diodes are connected from all indicated punch numbers to function in direction shown in figure 6.]

Character	Punch number						
0	6		4	.	3	2	
1	6	5	4	.	3		
2	6	5	4	.			
3	6	5		.	3		
4	6	5		.		2	
5	6	5		.	3	2	
6	6	5	4	.		2	
7	6	5		.			
8		5	4	.		2	1
9		5	4	.	3	2	1
Decimal	6			.		2	
Stop	6			.		2	1
Slash	6			.	3		
Carriage return	6			.	3		1
Correct			4	.	3	2	
Delete	6	5	4	.	3	2	1
Minus	6		4	.		2	
z		5		.			1

Tape Punch

The Friden Model SP-2 motorized tape punch takes the output from the control cabinet and punches the preselected codes on a paper tape. The punch is shown in figure 9. The motor runs continuously. A clutch turns the tape-punch drive shaft one revolution each time its magnet is energized. Three contacts, operated by cams on the tape-punch drive shaft, provide the signals to move the stepping switch one step for each drive shaft rotation, to energize the punches, and to prevent more than one rotation of the drive shaft at a time. The settings of the cams are shown in figure 10.

DETAILS OF OPERATION

The encoder, control cabinet, and tape punch are connected as shown in figure 11. If desired, the encoder can be disconnected when the tape is punched through the keyboard.

Since the tape punch can be operated from either the keyboard or the

TABLE 2.—Wiring of connectors for cable connecting control cabinet to Digi-Coder

Function	Control cabinet connector symbol	Digi-Coder connector symbol
0 (code board)	S	B, BB (both plugs)[1]
1 (code board)	V	D, DD (both plugs)[1]
2 (code board)	U	F, FF (both plugs)[1]
3 (code board)	N	J, JJ (both plugs)[1]
4 (code board)	J	L, LL (both plugs)[1]
5 (code board)	T	A, AA (both plugs)[1]
6 (code board)	L	C, CC (both plugs)[1]
7 (code board)	M	E, EE (both plugs)[1]
8 (code board)	C	H, HH (both plugs)[1]
9 (code board)	K	K, KK (both plugs)[1]
10^3 (stepping switch)	H	W (10-1 plug); MM, NN (1000-100 plug)
10^2 (stepping switch)	R	X (10-1 plug); M, N (1000-100 plug)
10^1 (stepping switch)	P	M, N (10-1 plug)
10^0 (stepping switch)	Q	MM, NN (10-1 plug)
To relay No. 2	E	T (both plugs)
To interrupter switch	D	U (both plugs)
To deck C wiper on stepping switch and sweep-start switch	F	V (both plugs)
To deck C on stepping switch and sweep-start switch	G	R (both plugs)
To relay No. 2	A	S (both plugs)
To selector switch	B	P (both plugs)
		Y, Z (not used)

[1] All like digits (0-9) on all drums (10^0, 10^1, 10^2, 10^3) are wired in parallel at Digi-Coder connectors.

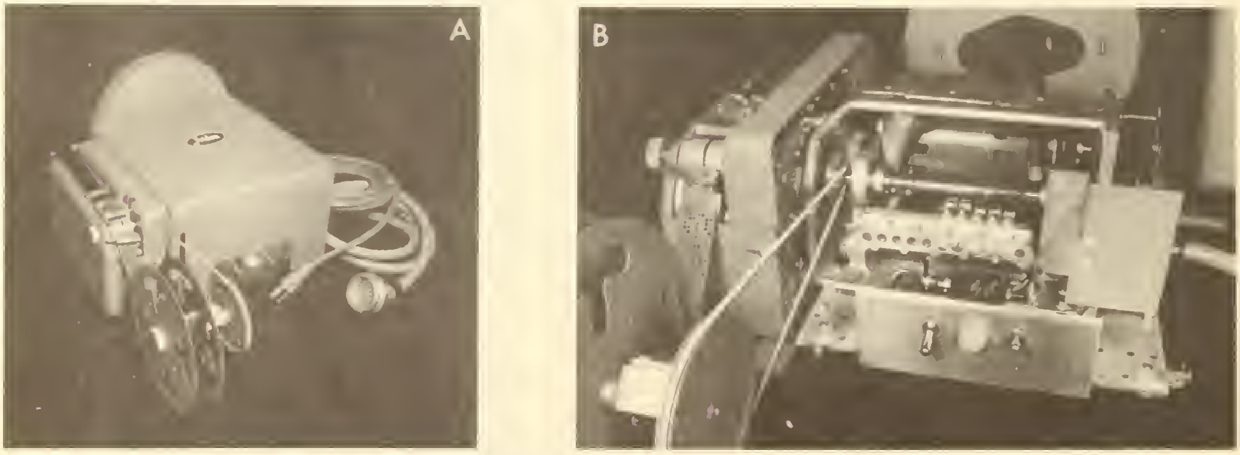

Figure 9.—Friden Model SP-2 tape punch: A, Cover on. Punches at left, tape supply reel at top, tape rewind reel at front, control panel at front, and power and control cables at right. B, Cover off. Clutch at right behind shield, three cams on punch drive shaft operate control switches, motor at rear, and punches at left.

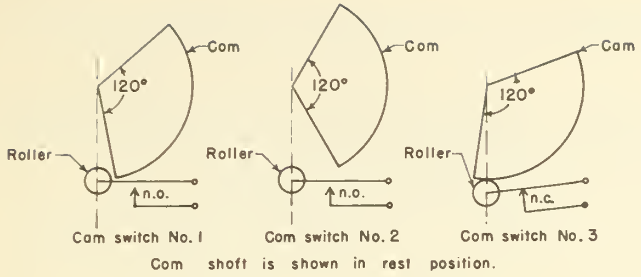

Figure 10.—Tape-punch cam switch settings.

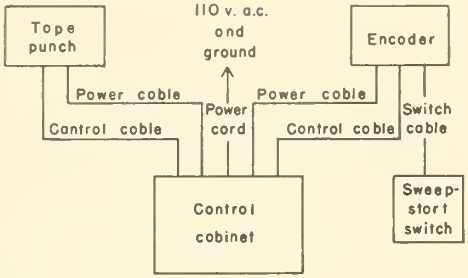

Figure 11.—Hook-up diagram.

encoder, descriptions of both methods of operation will be given. Reference to the circuit diagram (fig. 6) will make it easier to understand the circuit operation.

Tape-Punch Operation from the Keyboard

Operating Procedure

1. Turn the power switch to "on."
2. Move the selector switch to the "keyboard" position.
3. Depress the selected keyboard push button(s) to punch the coded symbol(s) on the tape.
4. To expel unpunched tape, depress the tape-feed switch.

Explanation of the Circuit Operation

1. The power switch supplies power to the equipment.
2. The selector switch provides the necessary power supply connections for the keyboard circuit elements.
3. Each keyboard push-button switch energizes the tape-punch clutch and the proper combination of punches as programmed by the diode matrix code board.
4. The tape-punch clutch and punch magnets receive current through the n.c. (normally closed) contacts of relay No. 1 and tape-punch cam switch No. 3. The circuit is completed through the corresponding matrix code board diodes and the depressed keyboard push-button switch.
5. The tape-punch punch shaft starts turning to punch the tape.
6. Tape-punch cam switch No. 3 opens and switch No. 1 closes at the beginning of the punch cycle, thereby removing current from the clutch and punch magnets and energizing relay No. 1, which also removes current from the clutch and punch magnets after one punch cycle.
7. Relay No. 1 remains energized as long as a keyboard push-button switch is depressed, its circuit being completed through the diode matrix code board and closed keyboard push-button switch.
8. The tape-punch clutch and punch magnets remain inactive after one punch cycle until the keyboard button is released.

9. When the keyboard button is released, relay No. 1 is deenergized and the contact returns to the n.c. position.
10. Diodes D_5 to D_9 prevent the shorting together of digits 5 to 9 on the diode matrix code board when the selector switch is in the keyboard position, at which time the Digi-Coder heads are up and shorting these digits.
11. Diode D_{14}, located across the coil of relay No. 1, suppresses high voltage transients and prevents contact arcing.
12. Except when a keyboard push button is depressed, the depressed feed switch energizes the tape-punch clutch magnet and expels unpunched tape from the tape punch.
13. The tape-punch clutch magnet receives current through the n.c. contacts of relay No. 1 and tape-punch cam switch No. 3 as before, and the circuit is completed through the closed tape-feed switch.
14. The clutch diodes on the diode matrix code board prevent the tape punches from being energized while the tape-feed switch is closed.
15. Diode D_4 prevents relay No. 1 from being energized through tape-punch cam switch No. 1 while the tape-feed switch is closed.

Tape-Punch Operation from the Encoder

Operating Procedure

1. Turn the power switch to "on."
2. Move the selector switch to the "encoder" position.
3. Set the decimal selector to the desired position.
4. Set the point gage at the desired position.
5. Depress the sweep-start switch to record the Digi-Coder contacts as coded punched holes on the tape.
6. Do not depress the tape-feed switch to expel unpunched tape during the readout cycle.

Explanation of the Circuit Operation

1. The power switch supplies power to the equipment.
2. The selector switch provides the necessary power supply connections for the encoder circuit elements.
3. The sweep-start switch turns on the Digi-Coder power supply. This pulls the Digi-Coder heads into readout position.
4. A Digi-Coder switch opens and inserts a series resistor in the circuit to reduce the head magnet current.
5. When the Digi-Coder heads are in readout position, the Digi-Coder advance contact switch closes and supplies current to the stepping switch interrupter switch. This energizes the sweep magnet to advance the stepping switch one position.

6. Current is supplied to the Digi-Coder advance contact through the closed sweep-start switch contacts and the n.c. contacts of relay No. 2.
7. With current applied to the stepping switch interrupter switch, the stepping switch advances one step from the home position to the deck A z position. This connects the z code section of the diode matrix code board to ground through the deck A wiper and the encoder selector switch position.
8. Simultaneously, the first position on stepping switch deck B supplies current to the tape-punch clutch and punch magnets through the closed contacts of tape-punch cam switch No. 3.
9. The tape-punch punch shaft starts turning to punch the z code on the tape.
10. During the punch cycle, tape-punch cam switch No. 3 opens and removes current from the clutch and punch magnets.
11. Tape-punch cam switch No. 3 closes at the end of the punch cycle.
12. During the z punch cycle, tape-punch cam switch No. 2 closes and advances the stepping switch to the next position.
13. The first position of stepping switch deck B also supplies current to tape-punch cam switch No. 2. This energizes the stepping switch sweep magnet.
14. The next stepping switch position after the deck A z position is blank, and the sweep magnet is again energized by deck B. This moves the stepping switch to position A' on deck A.
15. If the decimal selector is set to position A', section C of the decimal selector switch connects the decimal section of the diode matrix code board to ground through the stepping switch deck A wiper and encoder selector switch position.
16. Section A of the decimal selector switch supplies current through the closed contacts of tape-punch cam switch No. 3 to the clutch and punch magnets.
17. Section A of the decimal selector switch obtains current from the stepping switch deck B A position.
18. Section B of the decimal selector switch is not connected when the decimal selector is in the A position.
19. The tape-punch punch shaft turns and punches the decimal code on the tape.
20. Operations 10 and 11 are repeated.
21. During the punch cycle, tape-punch cam switch No. 2 closes and advances the stepping switch (see operation 13) to the deck A 10^3 position.
22. The Digi-Coder heads, which are still down, read the 10^3 digit and connect the corresponding tape-punch clutch and punch magnets to the stepping switch deck A 10^3 position through the diode matrix code board.
23. Simultaneously, deck B applies current through the closed contacts of tape-punch cam switch No. 3 to the clutch and punch magnets.
24. The tape-punch punch shaft turns and punches the 10^3 digit code on the tape.
25. Operations 10 and 11 are repeated.
26. During the punch cycle, tape-punch cam switch No. 2 closes and advances the stepping switch (see operation 13) to the deck A B' position.

27. Since the decimal selector has been previously set in the A' position, stepping switch deck B position B will advance the stepping switch by supplying current to the interrupter through the shorted section B of the decimal selector switch.

28. The stepping switch now advances to the deck A 10^2 position and reads out the 10^2 digit as before (see operations 22 through 25).

29. Operations 26, 27, and 28 will continue through the 10^0 digit until the stepping switch comes to the deck A CR (carriage return) position.

30. At the CR position, stepping switch deck A will connect the CR section of the diode matrix code board to ground through the stepping switch deck A wiper and the encoder selector switch position.

31. Stepping switch deck B will supply current to the clutch and punch magnets as before.

32. The CR code is punched on the tape.

33. Operations 10 and 11 are repeated.

34. During the punch cycle, tape punch cam switch No. 2 closes and advances the stepping switch to the home position (see operation 13). This stops the sweep cycle.

35. Stepping switch deck C (make-before-break contacts) keeps the Digi-Coder power supply turned on. This keeps the Digi-Coder heads in readout position until after the deck A 10^0 digit is read out.

36. After the 10^0 digit is read out, the Digi-Coder heads lift until another sweep cycle is started (operation 3).

37. Relay No. 2 allows only one sweep cycle per sweep-start button depression by turning on after the stepping switch advances from home to the first or z position on deck A. Current supplied to the tape-punch clutch and punch magnets from the first position of stepping switch deck B (operation 8) also supplies relay No. 2, thereby removing current from the Digi-Coder advance contacts.

38. Relay No. 2 remains on as long as the sweep-start button is depressed. When the sweep-start button is released, relay No. 2 turns off and the contacts reset to the n.c. position until the next sweep cycle.

39. Diode D_{10} prevents operation of relay No. 1 during encoder operation.

40. Diode D_{11} prevents operation of the stepping switch sweep magnet while the tape-feed switch is closed and the selector switch is in the "encoder" position.

41. Diodes D_1 to D_3 prevent interaction of the various circuit timing functions.

42. Diodes D_{13} and D_{15}, located across the stepping switch sweep magnet and relay No. 2 coil, suppress high voltage transients and prevent contact arcing.

43. The tape-feed switch can be operated when the stepping switch is in the home position.

44. Current is supplied to the tape-punch clutch magnet from the home position of stepping switch deck B.

45. The circuit is completed through the closed tape-feed switch.

46. The clutch diodes on the diode matrix code board prevent the tape punches from being energized while the tape-feed switch is closed.

OPERATIONAL DIFFICULTIES AND ADJUSTMENTS

The most common operational difficulties experienced during debugging and subsequent operation of the digital point gage recorder lie in five main areas:

1. The misadjustment of the Digi-Coder contacts was and continues to be the most common cause of erratic readout. The Digi-Coder manual should be consulted for adjustment instructions.
2. Moisture causes erratic operation of the tape punch. Heating the control box and tape punch with a small hair dryer has eliminated this malfunction.
3. Defective diodes in the circuit and on the diode matrix code board cause erratic readout of the digits and circuit malfunctions. Defective diodes often are not identified by ordinary ohmmeter measurements. When they are not, suspected diodes should be removed from the circuit and checked under operating conditions of current and voltage.
4. Dirty switch and relay contacts cause malfunctions. Even though most of the circuit components are covered, the relay and stepping switch contacts should be periodically cleaned. The stepping switch should be lubricated according to the manufacturer's instructions after each 100,000 to 500,000 operations using a lubricating kit available from the manufacturer. The encoder contacts should be checked and cleaned. Defective keyboard push-button switches are also a source of trouble.
5. Extra digits were and continue to be occasionally punched in the tape. This appears to be characteristic of the tape punch and must be tolerated. C. H. M. van Bavel, chief physicist, U. S. Water Conservation Laboratory, Tempe, Arizona, has reported similar experiences by letter.

PERFORMANCE CHECKS

Several checks of performance were made before placing the digital point gage in operation. Additional checks were made after the equipment had been installed.

Preinstallation Checks

The keyboard was checked first. Each key was found to punch the correct code on the tape.

The decimal selector was found to insert the decimal at the proper point in the printout sequence as programmed on the stepping switch.

The code drums were checked at each units, tens, hundreds, and thousands digit. The punched tape readout through the stepping switch was found to be correct for each digit and each digit was located at its programmed point in the readout sequence. This was also a check of the adjustment of the encoder contacts.

The final preinstallation check was made by setting the point gage at intervals of 0.100 foot from 0.000 to 3.000. The punched tape was read at each point gage setting and multiplied by the computed gear train multiplication constant (0.6135923). A systematic error of 0.08 percent was found. The constant was changed to 0.6141 to correct for the systematic error. This error is possibly in the point gage rack, since the gears are all of high-precision quality.

The point gage settings were read out for both increasing and decreasing point gage readings. The average lag between increasing and decreasing readings was 0.0006 foot. The results of these checks are shown in figure 12, where it can be seen that the punched tape recorded the point gage settings to within 0.001 foot.

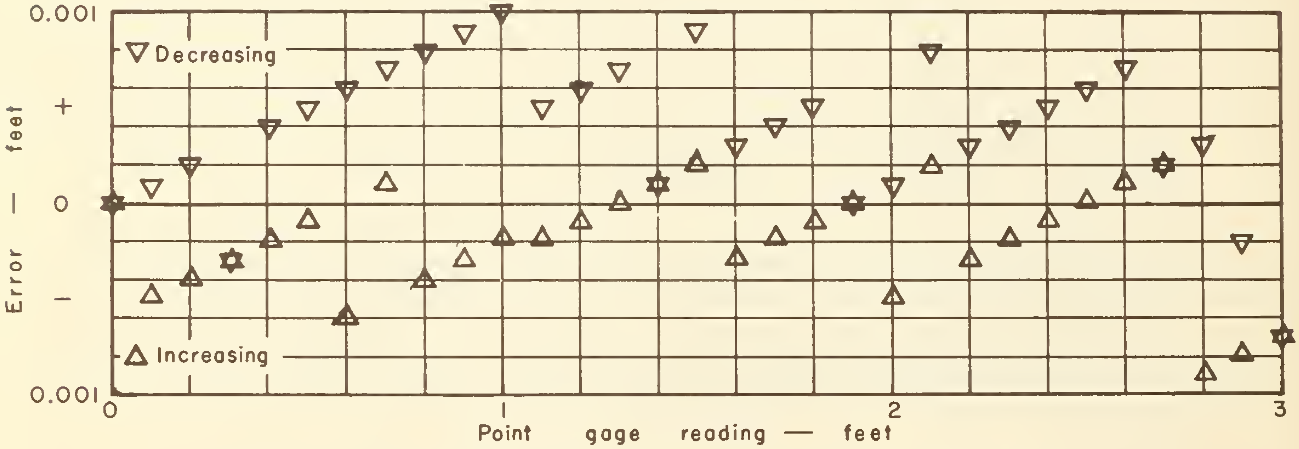

Figure 12.—Difference between tape-punch readout and point gage readings.

Postinstallation Checks

The equipment should be checked occasionally to make sure it is in adjustment and operating properly.

Diode Matrix Code Check

A check tape can be punched through the keyboard. The code punched for each character should agree with the punch numbers listed in table 1. An erroneous punch code indicates that the diodes should be checked.

There is no keyboard button switch for the z character, which is used only during the encoder readout but the z diode matrix can be checked by connecting a jumper wire between the z terminal on the diode matrix code board (see fig. 6) and ground. The selector switch must be in the "keyboard" position. The jumper wire acts as a switch, since every time it makes contact the tape punch punches the z code.

Stepping Switch Check

In order to provide an independent check of the stepping switch after the matrix diodes have been checked, it is necessary to disconnect the encoder and jumper-in a known four-digit number at the Digi-Coder connectors. The desired jumper wire contacts can be selected from table 2. The connections are made by jumpering the selected units or $\underline{10}^0$ digit from its connector contact to the $\underline{10}^0$ contact, the selected tens or $\underline{10}^1$ digit from its connector contact to the $\underline{10}^1$ contact, and so forth.

An example will illustrate the jumpering procedure. To record the number 1357, where $\underline{10}^0 = 7$, $\underline{10}^1 = 5$, $\underline{10}^2 = 3$, and $\underline{10}^3 = 1$, remove the two Digi-Coder connectors at the encoder cabinet and install the following jumper wires at the connectors (refer to fig. 6 and table 2 for the proper connections):

Connector		Digit		Power
$10^1 - 10^0$ or (10 - 1)	jumper from	E or EE	to	MM or NN
$10^1 - 10^0$ or (10 - 1)	jumper from	A or AA	to	M or N
$10^2 - 10^3$ or (1000 - 100)	jumper from	J or JJ	to	M or N
$10^2 - 10^3$ or (1000 - 100)	jumper from	D or DD	to	MM or NN

These four jumper wires set up the four-digit number 1357 for readout.

To initiate the readout cycle, set the decimal selector switch where desired, move the selector switch to the "encoder" position, and depress the sweep-start switch. The sweep-start switch makes connection only at the Digi-Coder connectors and will therefore function when the Digi-Coder connectors are disconnected from the encoder cabinet.

If the stepping switch is working properly, the programmed sequence (z, 1, 3, 5, 7, and CR in the example) should be punched with the decimal point at the selected position. See table 1 for the punch codes corresponding to the given characters and digits.

The stepping switch check can be done with any four-digit combination, thus simulating any encoder readout. If the readout contains no errors, then it can be assumed that the stepping switch is operating properly.

Encoder Check

A probable source of error is the Digi-Coder. To check the Digi-Coder, place the selector switch in the "encoder" position, then depress and hold down the sweep-start button. (The Digi-Coder heads will stay down until the sweep-start button is released.) Note the position of the irregular sensing pins and the corresponding code wheel on each of the four code drums. The sensing pins will be on a "hill," "plateau" or "valley" as shown in figure 3. No contact is made when the sensing pin is in the plateau position, as it should be for four of the five code wheels comprising each code drum. A hill or a valley position on a particular code wheel indicates a digit as follows:

Digit	Code wheel	Sensing pin
0	1	Hill
1	2	Hill
2	3	Hill
3	4	Hill
4	5	Hill
5	1	Valley
6	2	Valley
7	3	Valley
8	4	Valley
9	5	Valley

The digit obtained from this list should be compared with the digit punched on the tape. The corresponding tape-punch code is shown in table 1. An erroneous readout is an indication that the encoder needs adjustment. The contacts are the most likely source of trouble. Refer to the manufacturer's instruction bulletin for the methods of making the adjustments.

Since the proper adjustment of the Digi-Coder contacts is difficult to obtain the first time, it may be necessary to repeat the readout of the same number or point gage setting many times to establish that the proper adjustment has been made and to insure future accuracy.

Zero Check

The Digi-Coder has been adjusted so that its zero reading coincides with the zero setting of the point gage. If the Digi-Coder punches out something other than zero when the point gage is set at zero, this may be an indication of slippage of the adjustable gear on the Digi-Coder input shaft.